END-EFFECTOR - JOINT CONJUGATES FOR ROBOTIC ASSEMBLY OF LARGE TRUSS STRUCTURES IN SPACE: A SECOND GENERATION

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ABSTRACT

Attachment of strut to node can be accomplished with a variety of mechanisms: references [1,2,3,4]. All require extensive standoff elements (called scars) added to the nodes. These increase packaging volume for the nodes by as much as 300%. First generation designs also tend to be either heavy or expensive due to complex parts. This investigation focuses on screw thread mechanisms as the simplest and most easily manufactured of alternatives. Torque and rotational motion must be transmitted across the strut to end-effector interface accomplishing the joining process and establishing a specified preload. Four drive mechanisms are considered: worm, helical, bevel, and differential gears. All are developed with the following criteria in mind.

1. Preload: 250 to 500 lbs.

2. Envelopes: 1.0" strut; 2.5" node (reduce violation of specified diameters to a minimum)

3. Cost Reduction: reduce part complexity, diversity and count; increase "off the shelf" part fraction

4. Feedback mechanisms: incorporate in strut design

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Introduction

Current designs, a first generation intended for robotic assembly, have given priority to the ease and certainty of the assembly process under less than ideal conditions with a minimum of sensory feedback. As a consequence they are either heavy or expensive and all exhibit a relatively low packaging density. Low packaging density is caused by extensive "scars" applied to the node, increasing its envelope diameter by as much as 150% . Strut envelopes are violated to a lessEr extent with diameters increased by 25% or more. This smaller percentage is still a significant problem owing to a much higher fraction of the packaged volume represented by struts. As structures in space become larger, packaging density becomes an important consideration.

Objectives

Develop end-effector - joint conjugates that do not violate the envelopes of a 2.5" diameter node or a 1.0" diameter strut.

Reduce cost by:
- increasing the fraction of "off the shelf" parts;
- reducing part complexity, diversity and count.

Incorporate feedback mechanisms as an integral part of the overall scheme.

Discussion

Attachment of strut to node can be accomplished with a variety of mechanisms: references [1, 2, 3, 4]. All require extensive scars or standoff elements added to the node. These permit compliance when a strut must be fitted between nodes whose separation distance is either greater or smaller than the length. Two methods that do not require standoffs are the screw thread and conical wedge (concrete anchor) [5]. They allow the node separation distance to be too great, but depend on distortion of the truss in the case when the distance is too small. The present effort is designed around the screwthread as the simplest and most easily manufactured of all alternatives.

Torque and rotational motion must be transmitted across the strut to end-effector interface accomplishing the joining process and establishing the requisite 250 to 500 lb. preload. Four drive mechanisms were considered: worm gear, helical gear, bevel gear and differential gear. A strut-end design based on the differential gear was developed because it is the most compatible with the drive mechanism used on a first generation end-effector currently under fabrication. Torque capacities of available differential gears that would fit within the 1" envelope could not overcome friction in the screw-threads generated by the requisite 250 lb. preload. Helical gears provide a much better basics for achieving the objectives of a 2nd generation based on screwthread assembly. Part complexity, count and cost are all reduced. Attaching a left-hand helical gear to the bolt shaft so that it "travels" with the bolt has an additional advantage: axial thrust will always assist in driving the bolt in the desired direction.

The traveling helical assembly (Fig. 1) was integrated into a strut-end design (Fig. 2) that incorporates features which assist in the assembly process.

Capture of the node by a robotically manipulated strut-end can be assisted by active feedback mechanisms, parts of which are embedded in the strut-end (Fig. 3) or by passive spring loading devices (Fig. 4) without feedback. Active feedback is interfaced with the end-effector by means of a probe inserted thru a slot in the strut envelope and into a receptacle drilled in a non-rotating axial "traveler". This probe can assist in axial translation of the bolt as well as in reading its location and the axial force applied to it.

References

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[4] Stout, D. A., "Joint Connector Concept", D-300-01-001, Jewett Automation, 2/8/88

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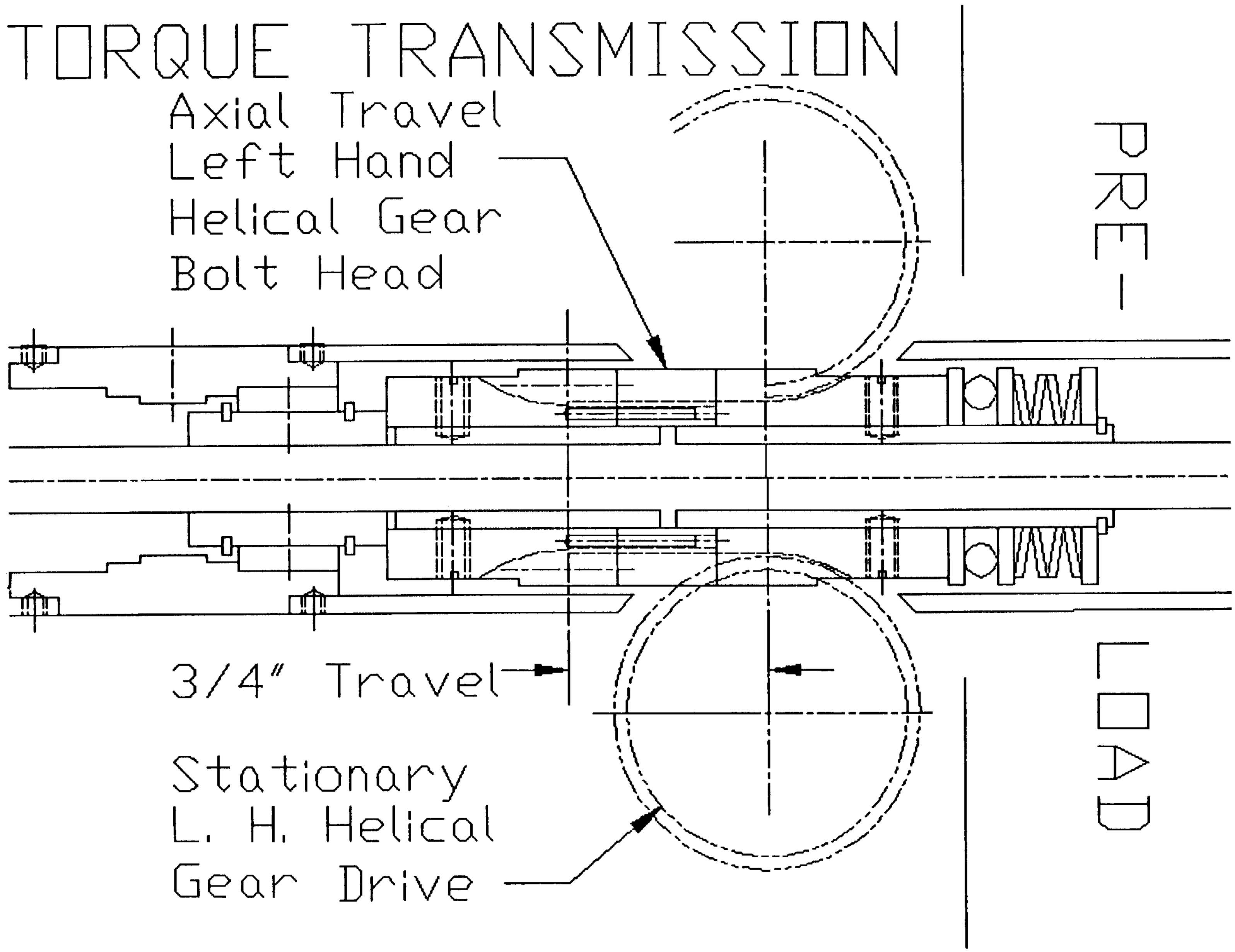
TORQUE TRANSMISSION
Axial Travel
Left Hand
Helical Gear
Bolt Head
3/4" Travel
Stationary
L. H. Helical
Gear Drive
PRE-
LOAD

Figure 1.

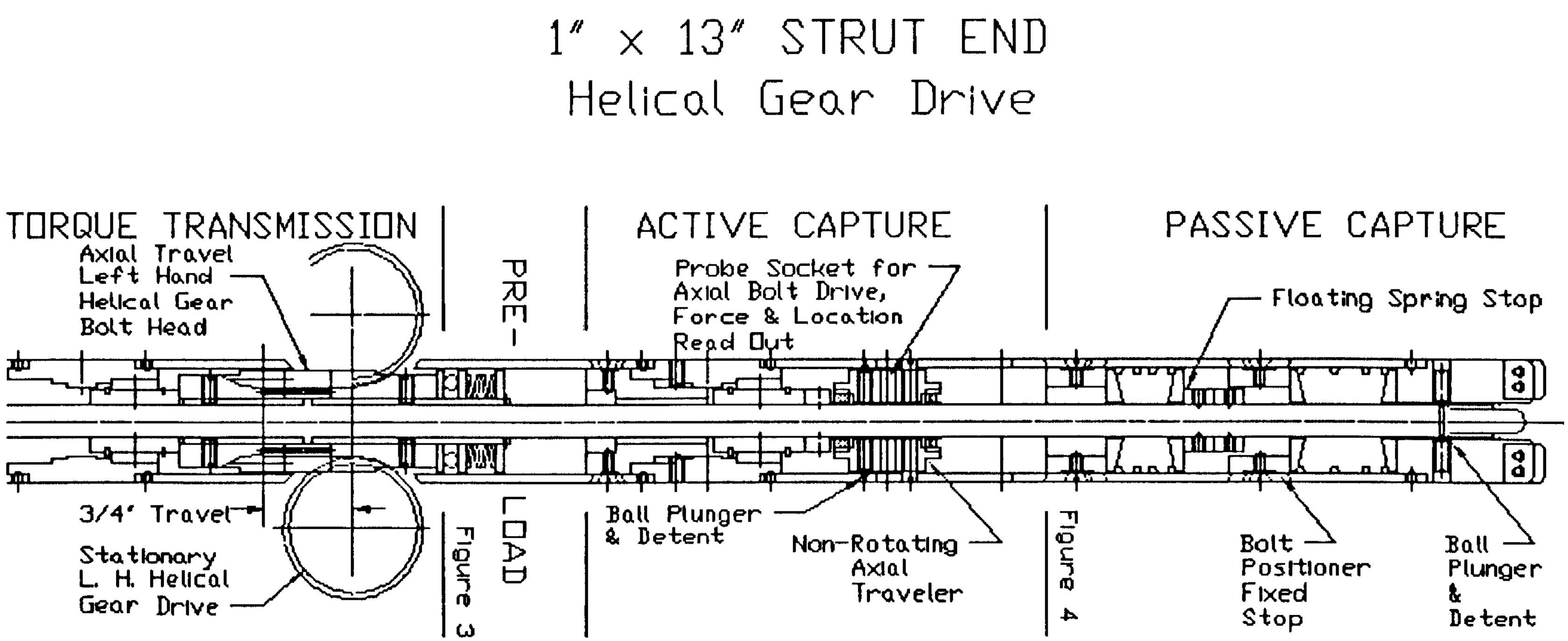
1" x 13" STRUT END
Helical Gear Drive
TORQUE TRANSMISSION
PRE-
LOAD
ACTIVE CAPTURE
PASSIVE CAPTURE
Axial Travel
Left Hand
Helical Gear
Bolt Head
3/4" Travel
Stationary
L. H. Helical
Gear Drive
Figure 3
Probe Socket for
Axial Bolt Drive,
Force & Location
Read Out
Ball Plunger
& Detent
Non-Rotating
Axial
Traveler
Figure 4
Floating Spring Stop
Bolt
Positioner
Fixed
Stop
Ball
Plunger
&
Detent

Figure 2.

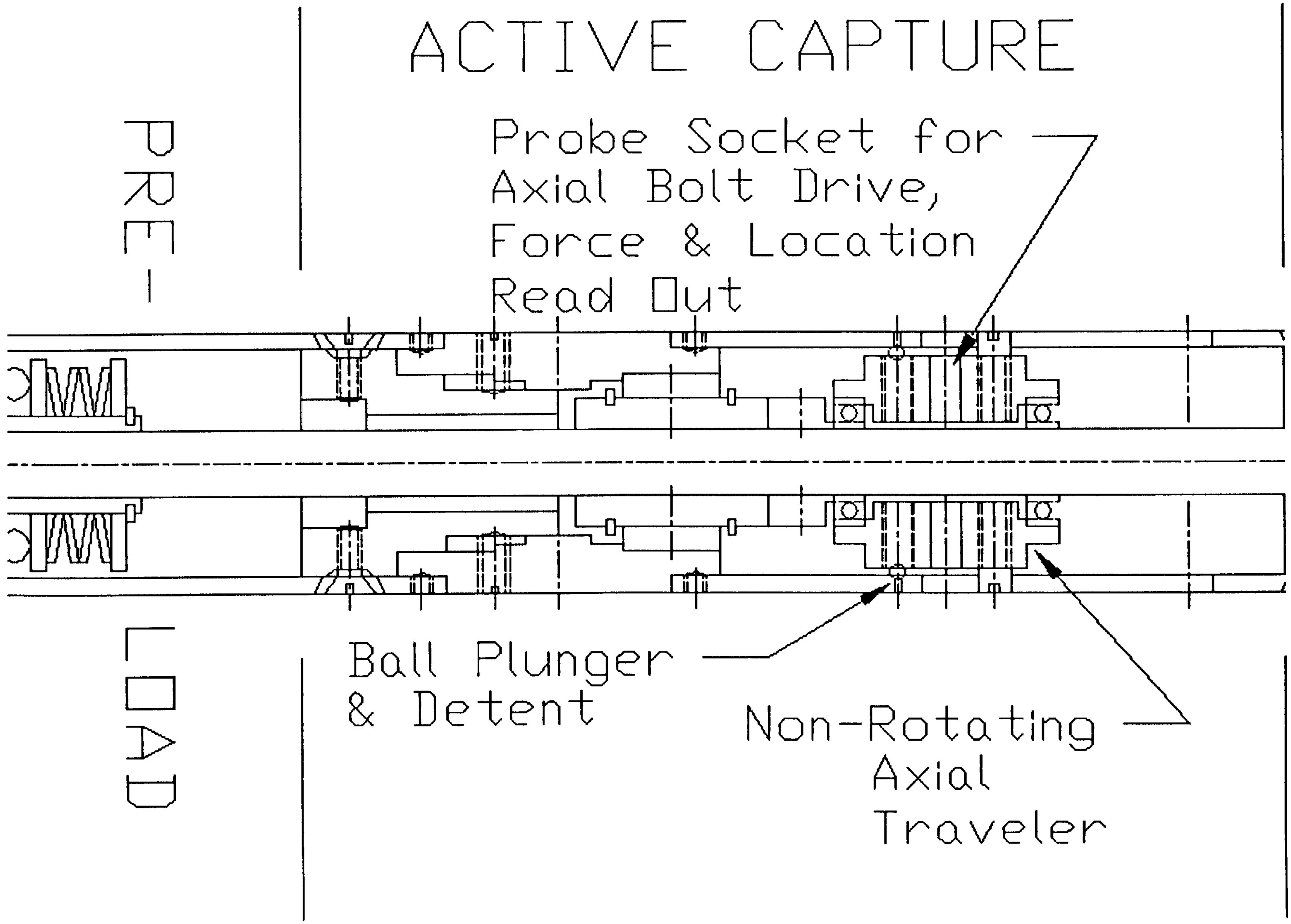
ACTIVE CAPTURE
PRE-LOAD
Probe Socket for
Axial Bolt Drive,
Force & Location
Read Out
Ball Plunger
& Detent
Non-Rotating
Axial
Traveler

Figure 3.

PASSIVE CAPTURE

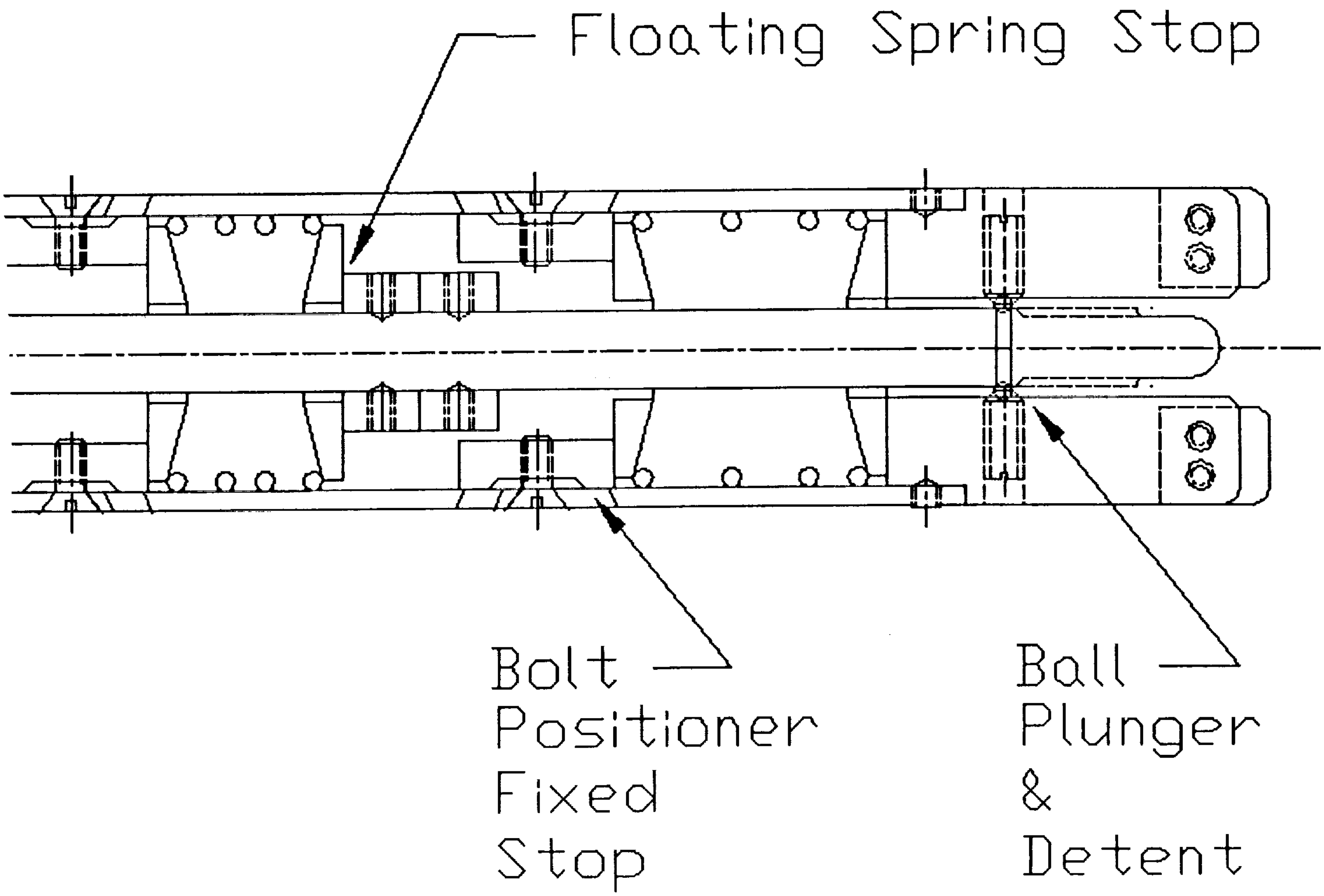

Figure 4.